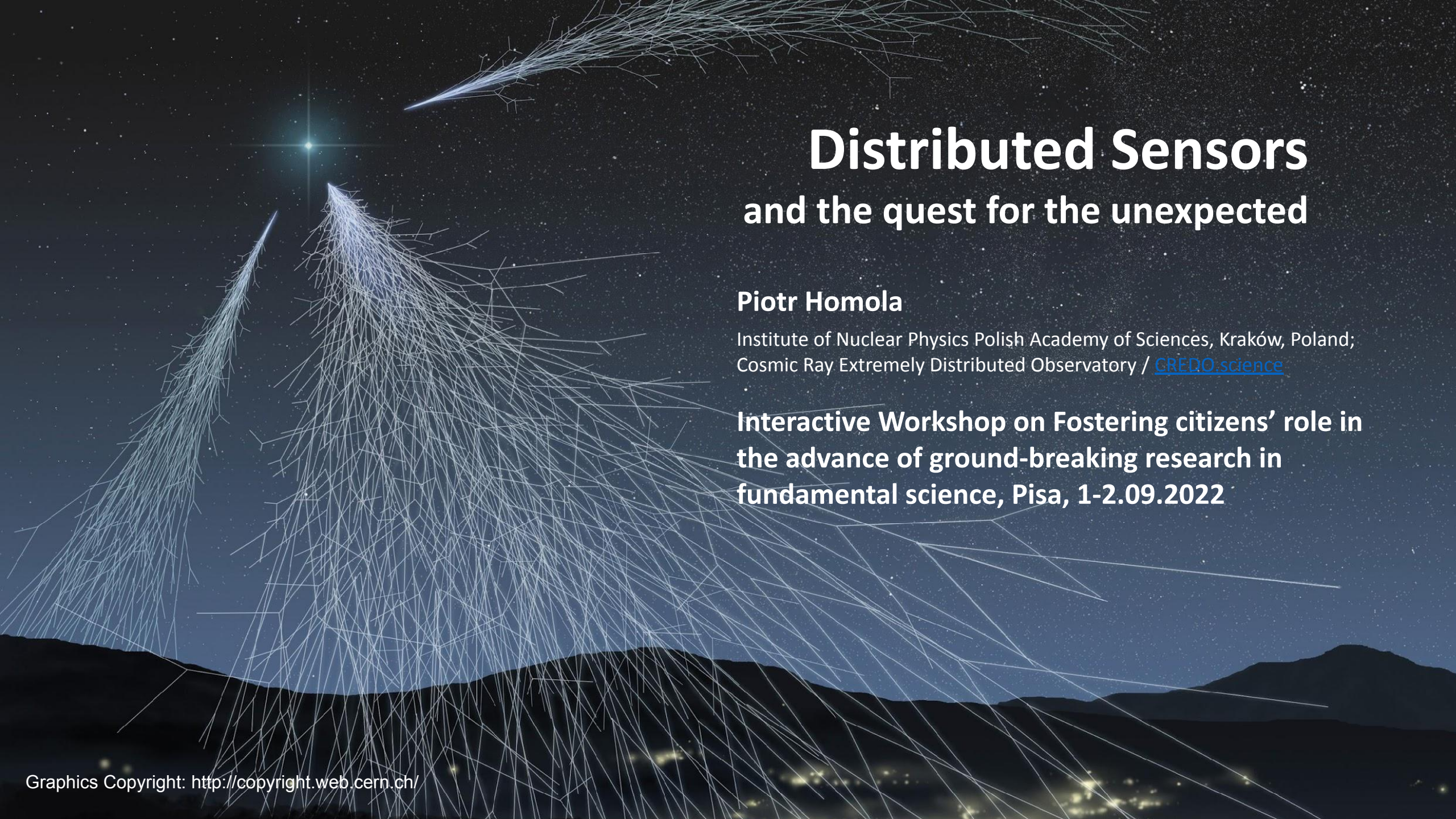


Distributed Sensors

and the quest for the unexpected

Piotr Homola

Institute of Nuclear Physics Polish Academy of Sciences, Kraków, Poland;
Cosmic Ray Extremely Distributed Observatory / CREDO science

Interactive Workshop on Fostering citizens' role in the advance of ground-breaking research in fundamental science, Pisa, 1-2.09.2022

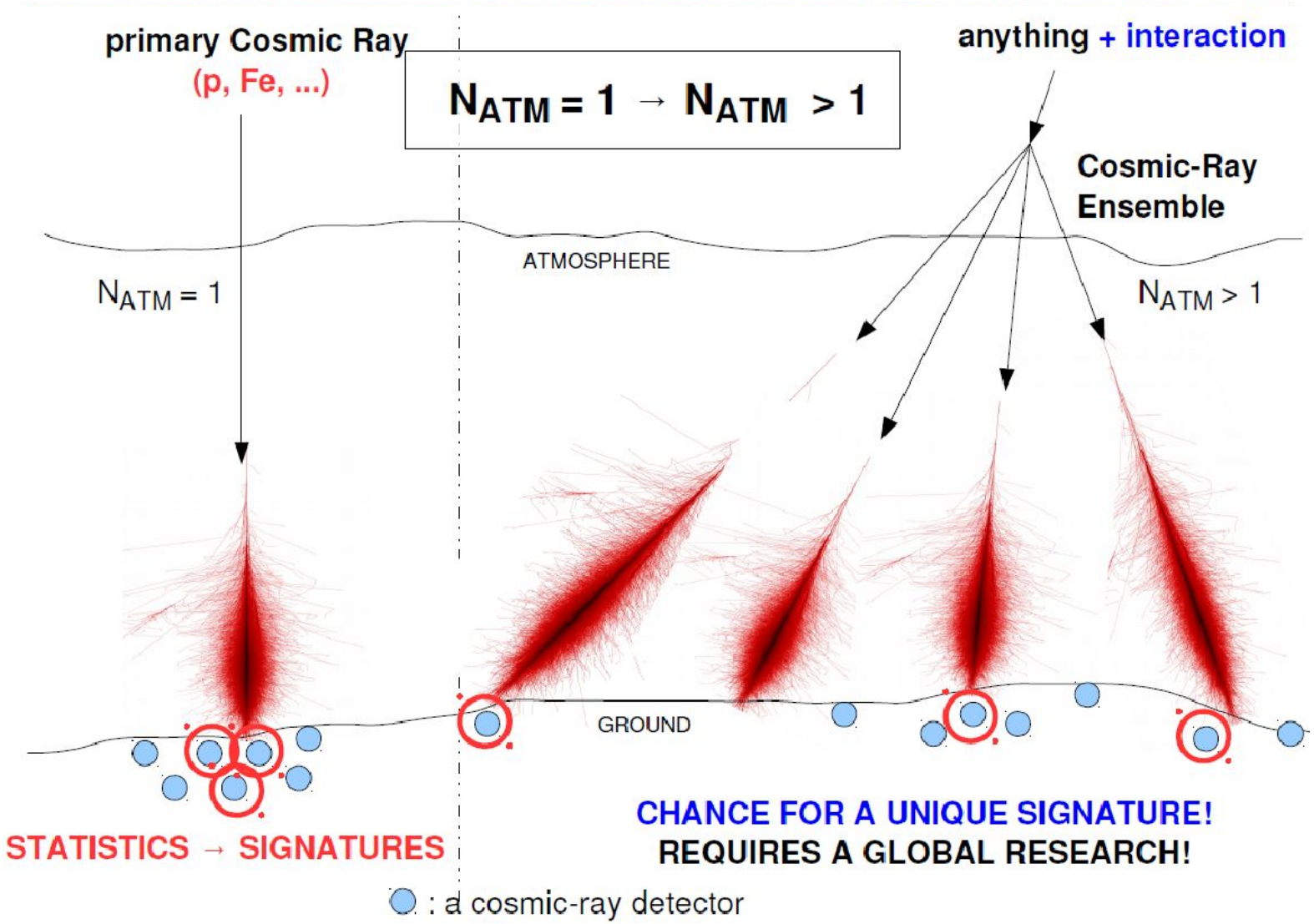
The Cosmic Ray Extremely Distributed Observatory Collaboration

CREDO
JOURNEY

key reference: *Symmetry* **2020**, *12*(11), 1835; **https://doi.org/10.3390/sym12111835**

2

Cosmic ray large scale correlations!

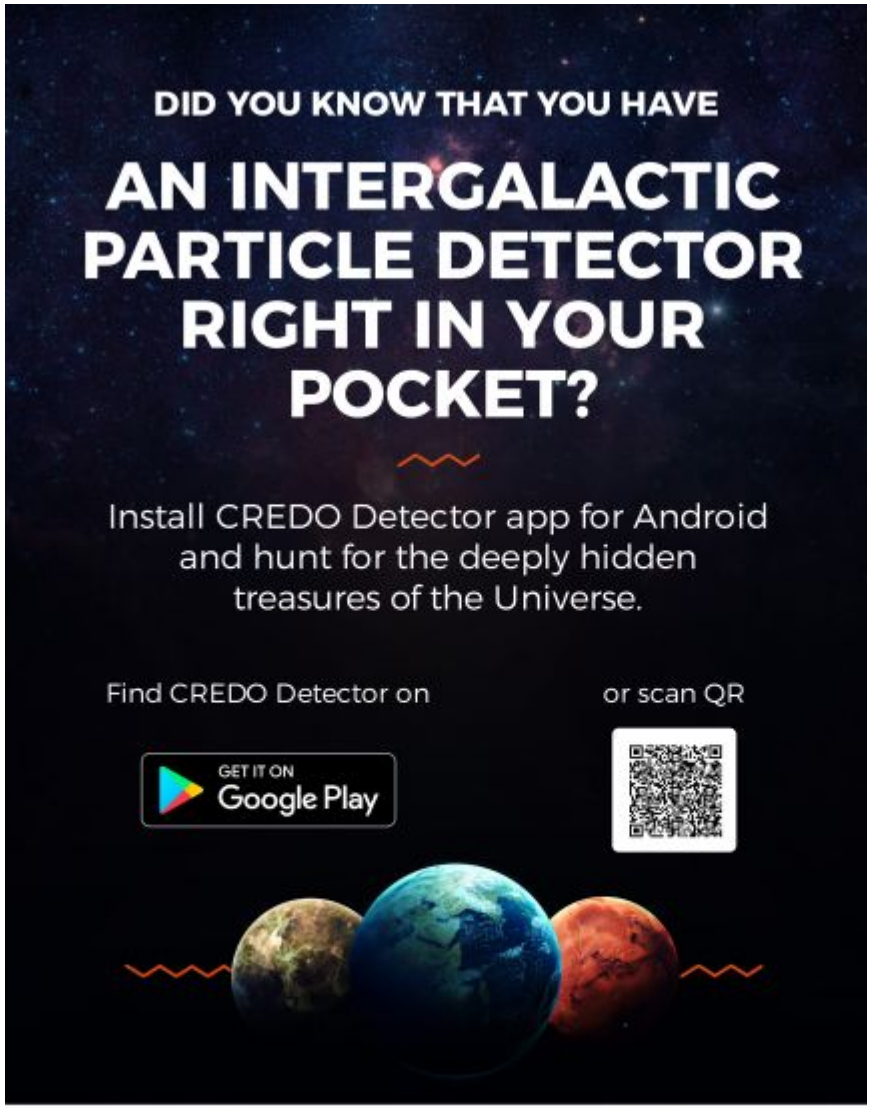


CREDO
THE QUEST FOR THE UNEXPECTED

The need for global solutions!

CREDO

THE QUEST FOR THE UNEXPECTED



CREDO: already global

46 institutions / 20 countries / 5 continents / ~ 15 700 users / ~ 12 000 teams / > 11 800 000 smartphone detections / > 1200 smartphone work years

CREDO Detector: what do we see?

[work in progress, e.g. at INP PAS]

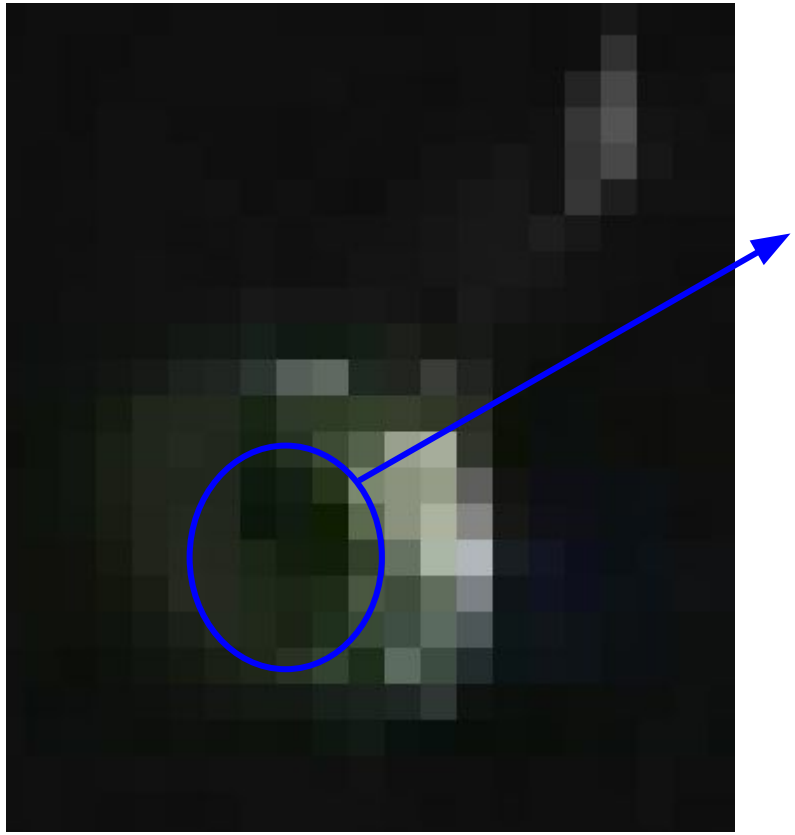
scenarios!

muons?

air showers ?

CRE?

“The quest for the unexpected”: particle track candidates and invaluable vigilance and curiosity of citizen scientists



“What is this, a mini black hole???”

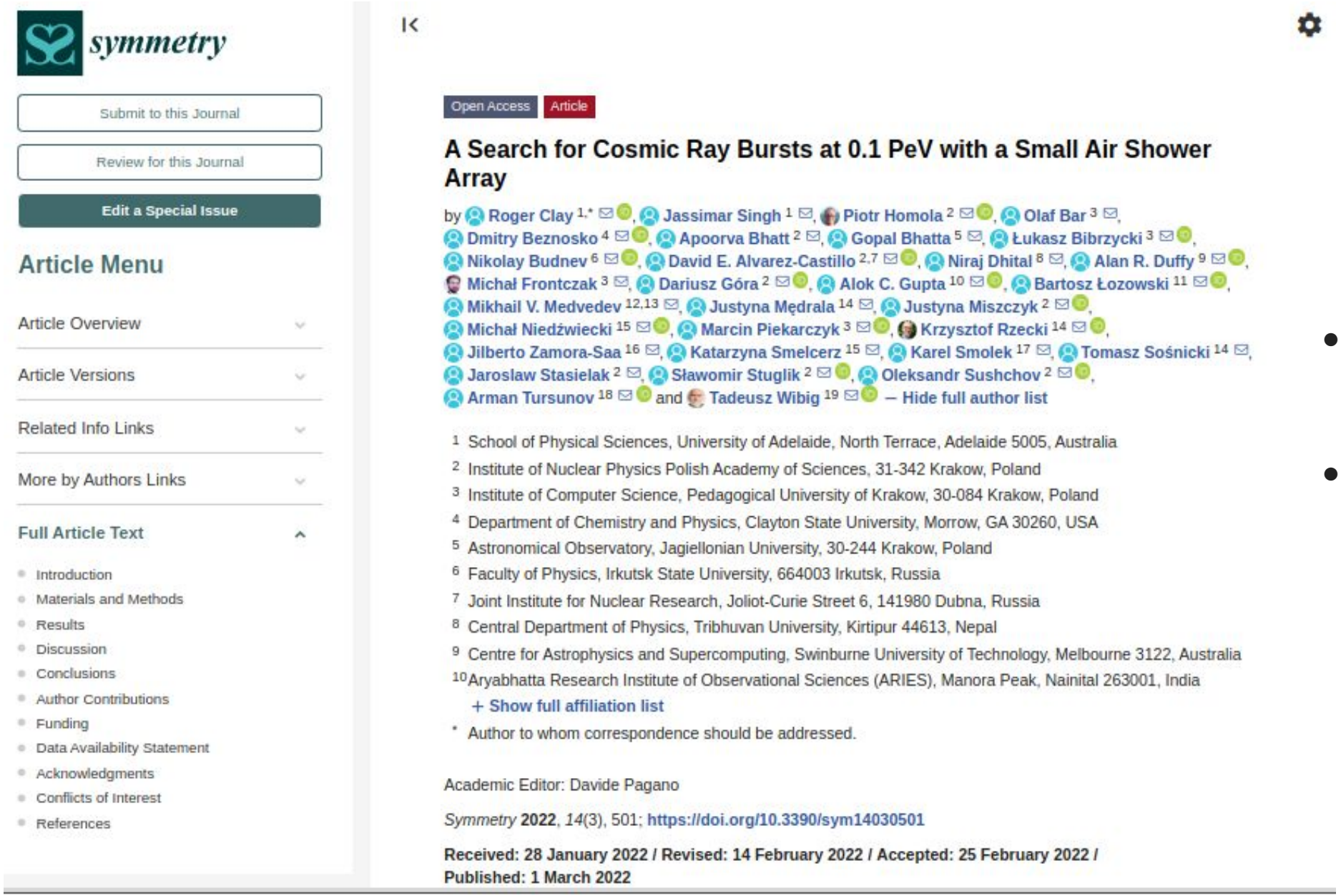
aplication: CREDO Detector, user Grzegorz,
detection: 2018-11-10

Disussion:
https://credo.science/credodetektor/viewtopic.php?f=4&t=17&start=60

Science highlights:

the unexpected “game changer” discovery candidates potentially sensitive to **breakthrough contributions by citizen scientists**:

event clusters & *cosmo-seismic* correlations



symmetry

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- Conclusions
- Author Contributions
- Funding
- Data Availability Statement
- Acknowledgments
- Conflicts of Interest
- References

Open Access Article

A Search for Cosmic Ray Bursts at 0.1 PeV with a Small Air Shower Array

by Roger Clay [1,*], Jassimar Singh [1], Piotr Homola [2], Olaf Bar [3], Dmitry Beznosko [4], Apoorva Bhatt [2], Gopal Bhatta [5], Łukasz Bibrzycki [3], Nikolay Budnev [6], David E. Alvarez-Castillo [2,7], Niraj Dhital [8], Alan R. Duffy [9], Michał Frontczak [3], Dariusz Góra [2], Alok C. Gupta [10], Bartosz Łozowski [11], Mikhail V. Medvedev [12,13], Justyna Mędrala [14], Justyna Miszczyk [2], Michał Niedźwiecki [15], Marcin Piekarczyk [3], Krzysztof Rzecki [14], Jilberto Zamora-Saa [16], Katarzyna Smelcerz [15], Karel Smolek [17], Tomasz Sośnicki [14], Jaroslaw Stasielak [2], Sławomir Stuglik [2], Oleksandr Sushchov [2], Arman Tursunov [18] and Tadeusz Wibig [19] – Hide full author list

1 School of Physical Sciences, University of Adelaide, North Terrace, Adelaide 5005, Australia
2 Institute of Nuclear Physics Polish Academy of Sciences, 31-342 Krakow, Poland
3 Institute of Computer Science, Pedagogical University of Krakow, 30-084 Krakow, Poland
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7 Joint Institute for Nuclear Research, Joliot-Curie Street 6, 141980 Dubna, Russia
8 Central Department of Physics, Tribhuvan University, Kirtipur 44613, Nepal
9 Centre for Astrophysics and Supercomputing, Swinburne University of Technology, Melbourne 3122, Australia
10 Aryabhatta Research Institute of Observational Sciences (ARIES), Manora Peak, Nainital 263001, India
+ Show full affiliation list
* Author to whom correspondence should be addressed.

Academic Editor: Davide Pagano

Symmetry **2022**, *14*(3), 501; https://doi.org/10.3390/sym14030501

Received: 28 January 2022 / Revised: 14 February 2022 / Accepted: 25 February 2022 / Published: 1 March 2022

- **4 bursts, time scale: < 1 min.; total chance probability: ~4σ**
- **additional properties:**
  - **clustering directions in 3 bursts**
  - **increasing time between events in bursts**

and: R. Clay, J. Singh, for the CREDO Collaboration, PoS(ICRC2021)298, https://pos.sissa.it/395/298/pdf;

The search for air shower clusters: Adelaide

R. Clay, J. Singh, for the CREDO Collaboration, PoS(ICRC2021)298, https://pos.sissa.it/395/298/pdf
(a conference report at the 37th International Cosmic Ray Conference 2021)

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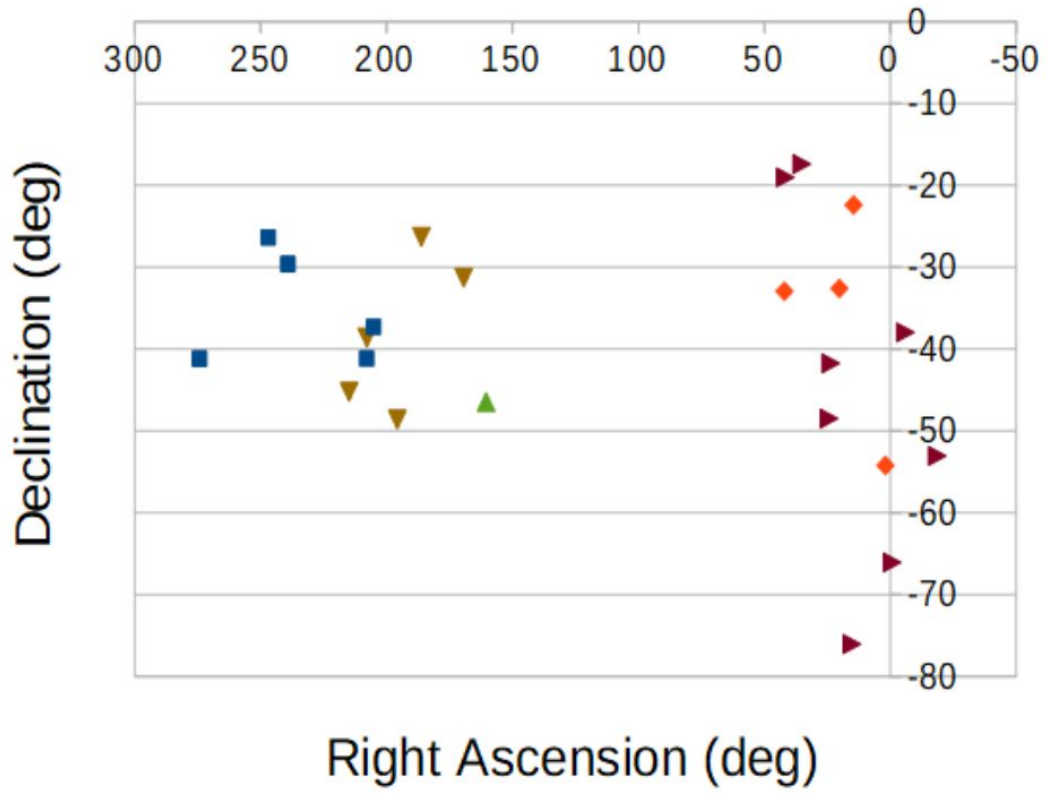


Figure 6. Scatter diagram of burst event arrival directions from five bursts.

Purple: 2019/07/19 Green: 2019/06/18

Blue: 2017/10/29 Red: 2017/10/10

Brown: 2017/10/08

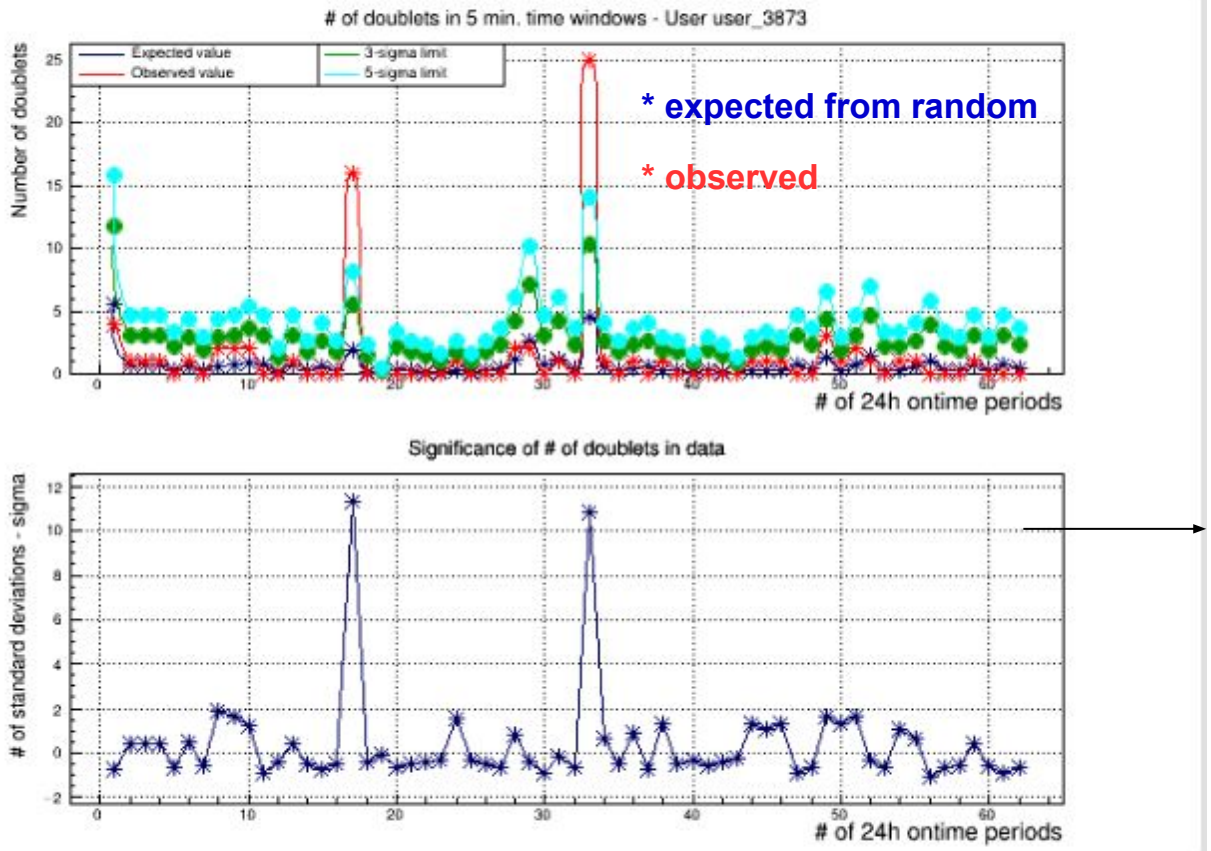
Ultimate statistical significance? Work in progress!

Quantum Gravity Previewer: online experiment!

Cumulative number of hit pairs („doublets”) within 5 min, in a single smartphone

by Kevin Almeida Cheminant, for the CREDO Collaboration

Number of doublets (two cosmic ray detections in an interval of 5 minutes) found in data (red) in every 24 hour period versus the expected value obtained from background simulations(dark blue). Number of doublets needed to obtain a 3 or 5 sigma effect are also given (green and light blue, respectively).



Significance of number of doublets (two cosmic ray detections in an interval of 5 minutes) found in data in every 24 hour period.

10σ

(significance)

See also the IFJ PAN / CREDO public release in EurekAlert!
HERE

Interdisciplinary potential: contribution to earthquake early warning system?

Physics > Geophysics

[Submitted on 26 Apr 2022]

Observation of large scale precursor correlations between cosmic rays and earthquakes

P. Homola, V. Marchenko, A. Napolitano, R. Damian, R. Guzik, D. Alvarez-Castillo, S. Stuglik, O. Ruimi, O. Skorenok, J. Zamora-Saa, J.M. Vaquero, T. Wibig, M. Knap, K. Dziadkowiec, M. Karpiel, O. Sushchov, J. W. Mietelski, K. Gorzkiewicz, N. Zabari, K. Almeida Cheminant, B. Idźkowski, T. Bulik, G. Bhatta, N. Budnev, R. Kamiński, M.V. Medvedev, K. Kozak, O. Bar, Ł. Bibrzycki, M. Bielewicz, M. Frontczak, P. Kovács, B. Łozowski, J. Miszczyk, M. Niedźwiecki, L. del Peral, M. Piekarczyk, M. D. Rodriguez Frias, K. Rzecki, K. Smelcerz, T. Sośnicki, J. Stasielak, A. A. Tursunov

The search for correlations between secondary cosmic ray detection rates and seismic effects has long been a subject of investigation motivated by the hope of identifying a new precursor type that could feed a global early warning system against earthquakes. Here we show for the first time that the average variation of the cosmic ray detection rates correlates with the global seismic activity to be observed with a time lag of approximately two weeks, and that the significance of the effect varies with a periodicity resembling the undecenal solar cycle, with a shift in phase of around three years, exceeding 6 sigma at local maxima. The precursor characteristics of the observed correlations point to a pioneer perspective of an early warning system against earthquakes.

Comments: 16 pages, 4 figures in the main article and 11 pages and 4 figures in the Suplementary Material

Subjects: **Geophysics (physics.geo-ph)**; Earth and Planetary Astrophysics (astro-ph.EP); High Energy Astrophysical Phenomena (astro-ph.HE); Solar and Stellar Astrophysics (astro-ph.SR)

Cite as: arXiv:2204.12310 **[physics.geo-ph]**

(or arXiv:2204.12310v1 **[physics.geo-ph]** for this version)

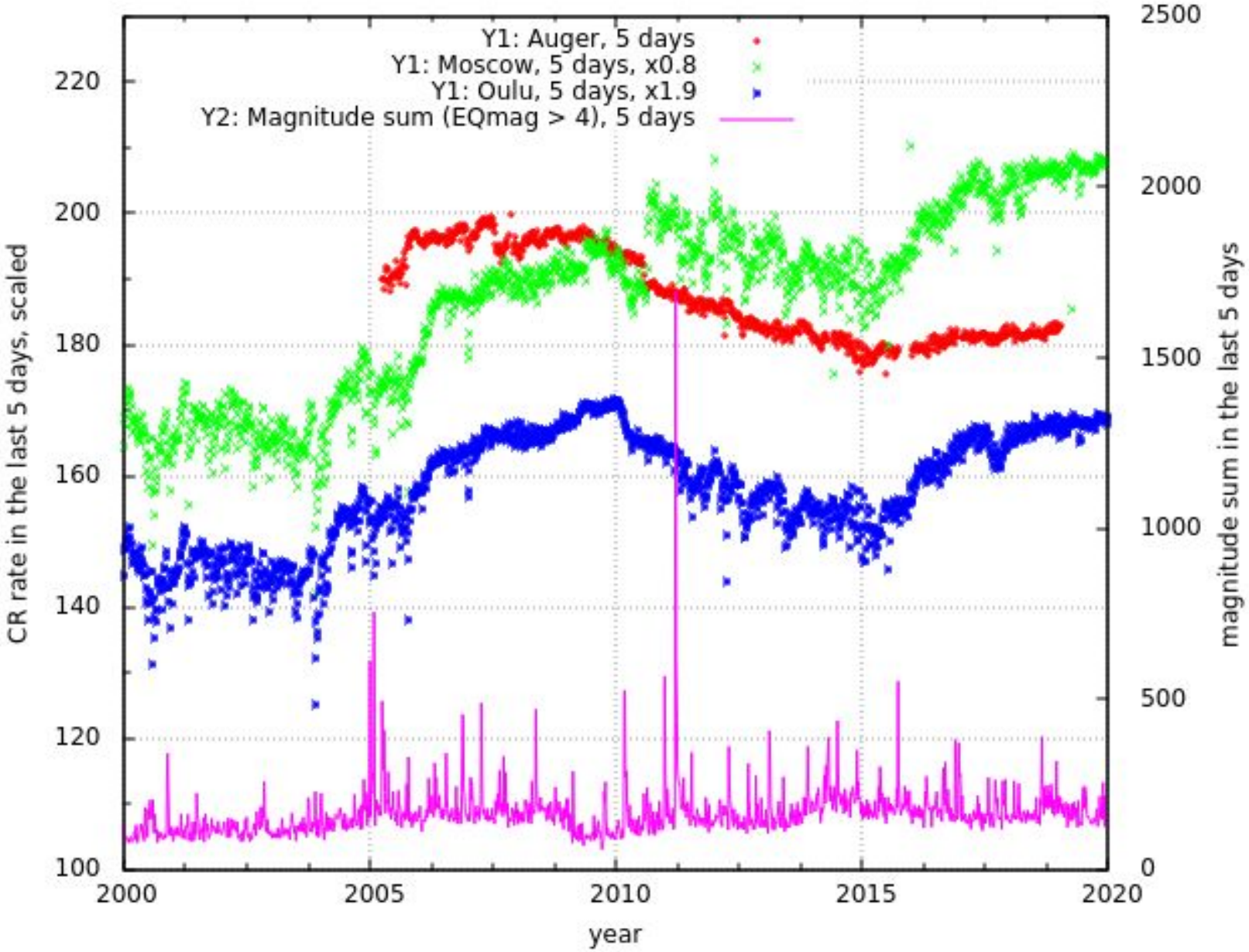
https://doi.org/10.48550/arXiv.2204.12310

Submission history

From: Piotr Homola Dr. [view email]

[v1] Tue, 26 Apr 2022 13:37:03 UTC (1,085 KB)

The data



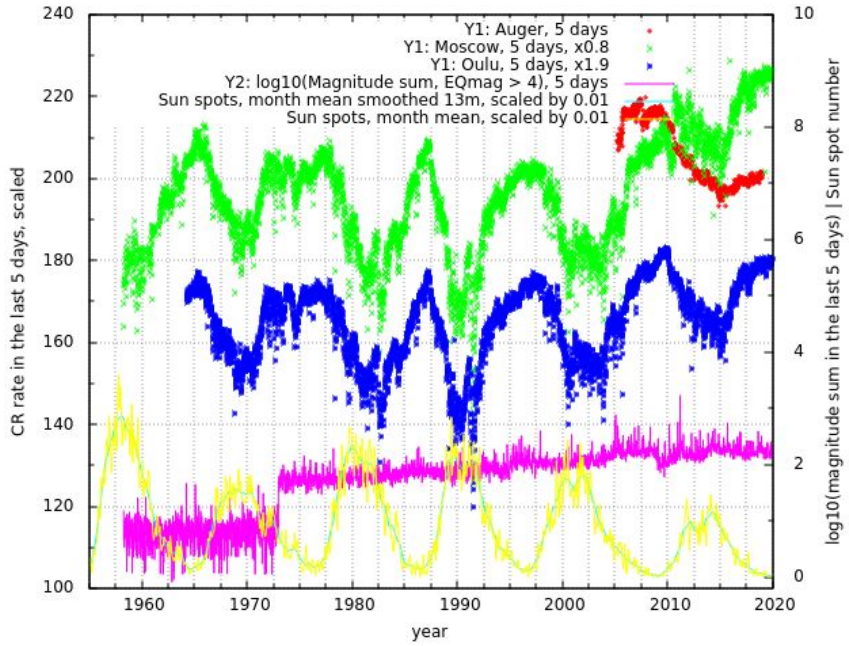
public resources of:

[Pierre Auger Observatory scaler data]

[Neutron Monitor Database]

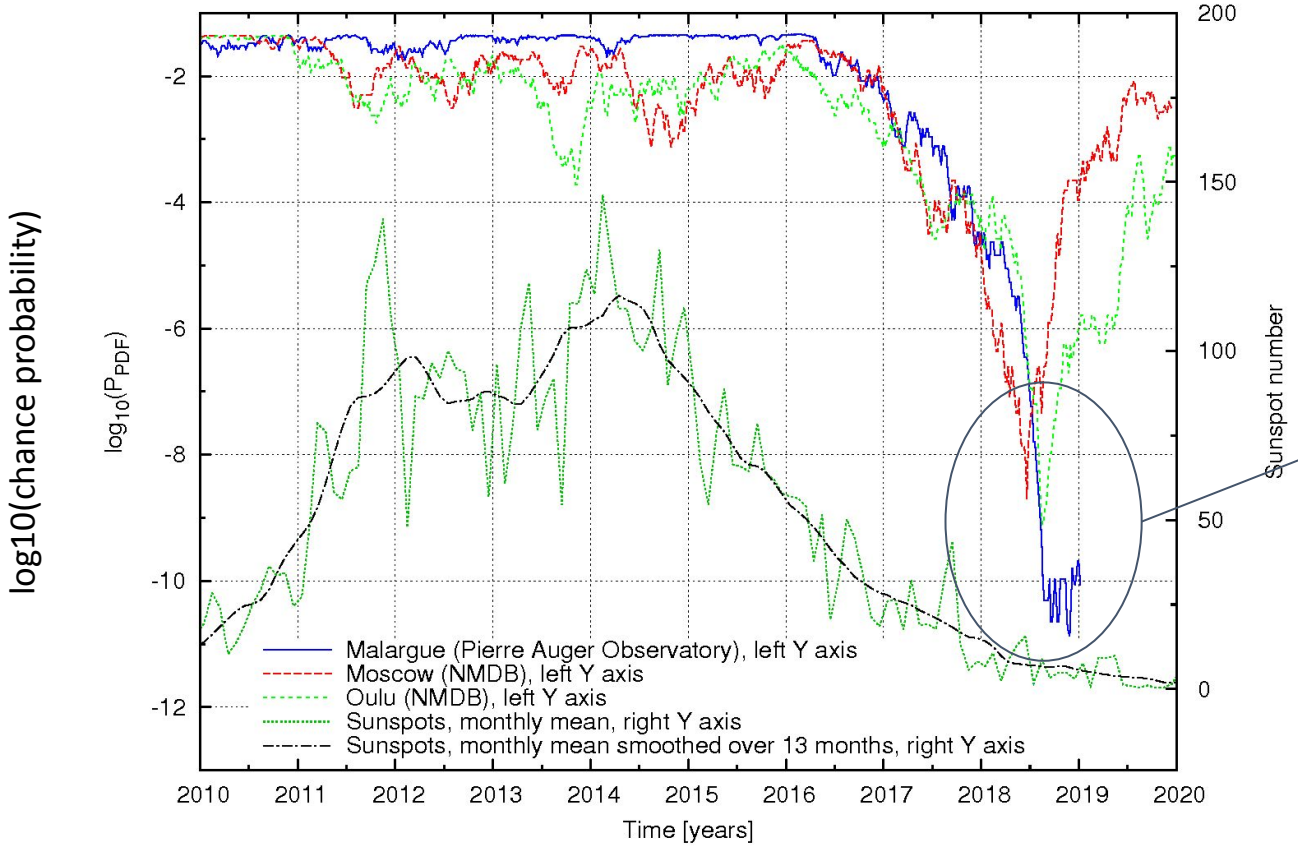
[U.S. Geological Survey]

[Solar Influences Data analysis Center]



Checking for a correlation $|dN_{CR}|$ vs. $\Sigma magnitude_{EQ}$ using **5-day bins** over ~**4.5 yr windows**

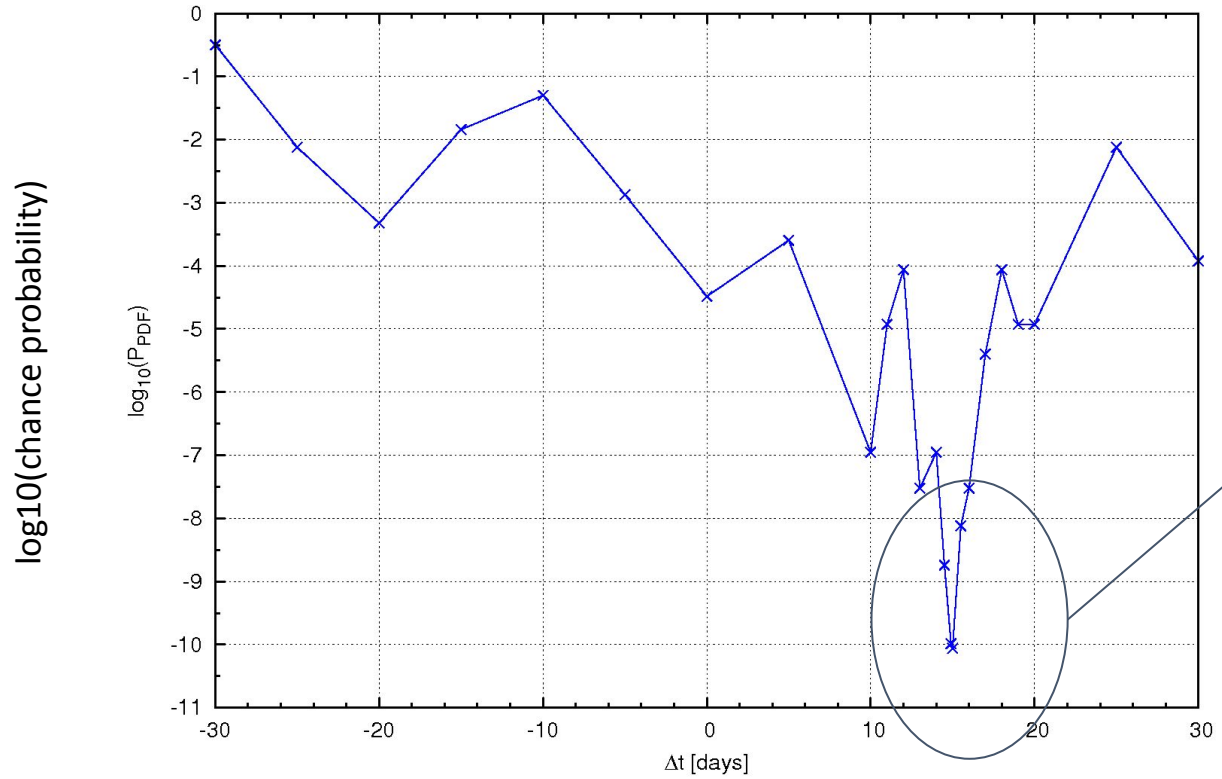
local cosmic dynamics vs. global seismicity: dependence on geographical location?



different cosmic ray sites see the correlation effect differently? Need for more detectors?

~6 σ significance of the effect in three technically independent CR data sets collected by the Moscow and Oulu NMDB stations, and by the Pierre Auger Observatory, compared to sunspot numbers. **Each point** illustrates the correlation effect during **the last ~4.5 years** (335 **five-day intervals**). All the significance curves were obtained after fine tuning of the parameter t_0 performed by applying 20 small shifts in time between 0 and 5 days.

Cosmic ray variation 15 days before the corresponding change in seismic activity!

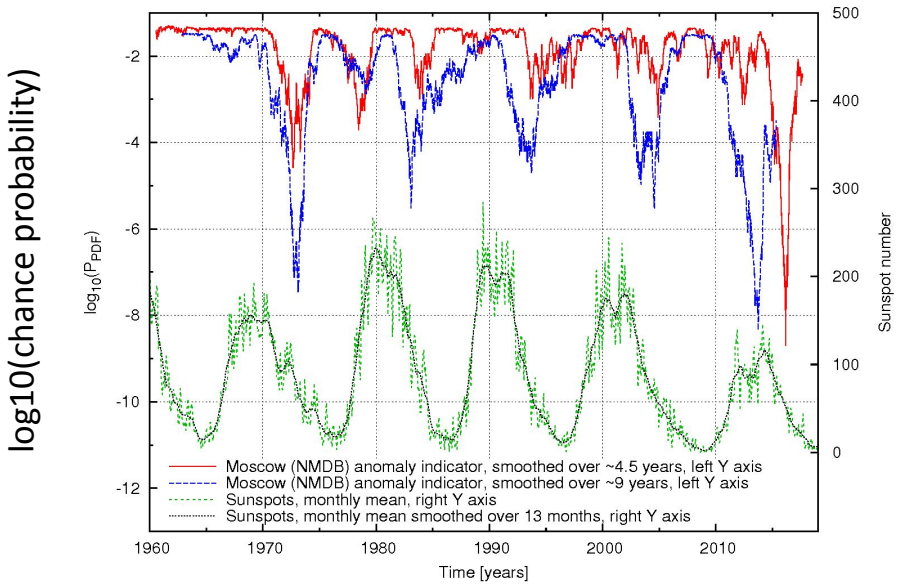


New perspective for an early warning system against earthquakes?

The dependence of the significance of the *cosmo-seismic* correlations on the time shift t of the EQ data with respect to the Auger CR data, for the optimum free parameter set defined in Eq. 1. The positive or negative values of t correspond to the situations in which one compares the secondary cosmic ray data in a given time interval to the seismic data recorded in time intervals in the future or in the past, respectively.

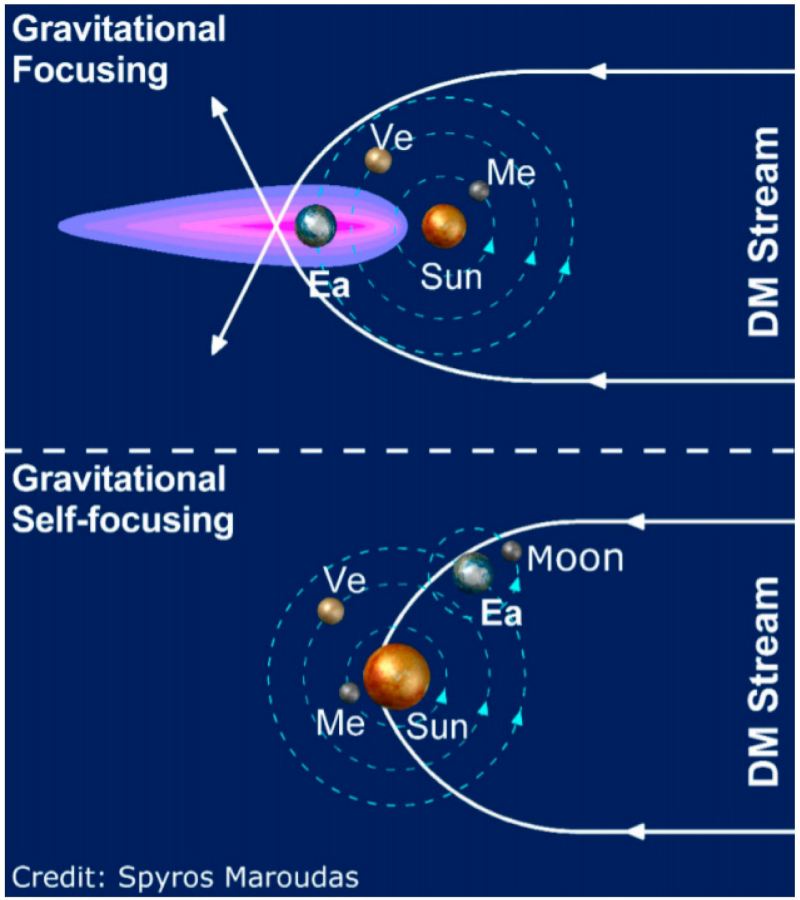
Interpretation: Role of the Sun or DM stream?

P. Homola et al., 2022: https://arxiv.org/abs/2204.12310



The anomaly indicator in the Moscow NMDB data set compared to the sunspot number. Each point on the correlation significance curves corresponds to the effect found over the smoothing window length of ~4.5 years (1675 days, in red) and ~9 years (3350 days, in blue), with the curve points located at the centers of the windows.

K. Zioutas et al., 2021
Phys. Sci. Forum **2021**, *2*(1), 10; https://doi.org/10.3390/ECU2021-09313



Predicting earthquakes?? Probing DM streams??? Testing Quantum Gravity scenarios??? With smartphones????
-> possible ultimate ambition: **cosmic ray station in every school and BTS station + citizen science**
-> organizational concept: e.g. **Open Multi Messenger Organization** (OMMO)

The breakthrough in science might come from citizen science…

→ large geographical spread

→ inter-collaboration cooperation

→ **massive public engagement**

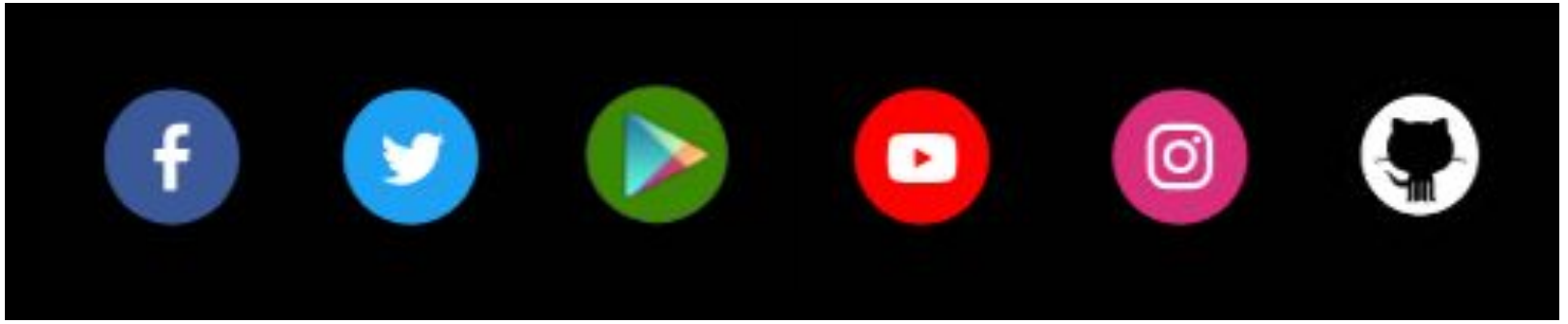
↓

citizen science might be an invaluable scientific tool!

backup

More about CREDO

https://credo.science



Personal contact:

Piotr Homola / CREDO Project Coordinator /
Piotr.Homola@credo.science / +48 502 294 333

astro/cosmo/geo/bio/eco/hi-tech/... infrastructure

CREDO detectors today

CREDO Detector (Android app, ~2M track candidates, origin: IFJ PAN)

cosmicrayapp.com (iOS, ~7M track candidates, origin: Canada)

CREDO Web Detector (Chrome, in tests, origin: Kraków)

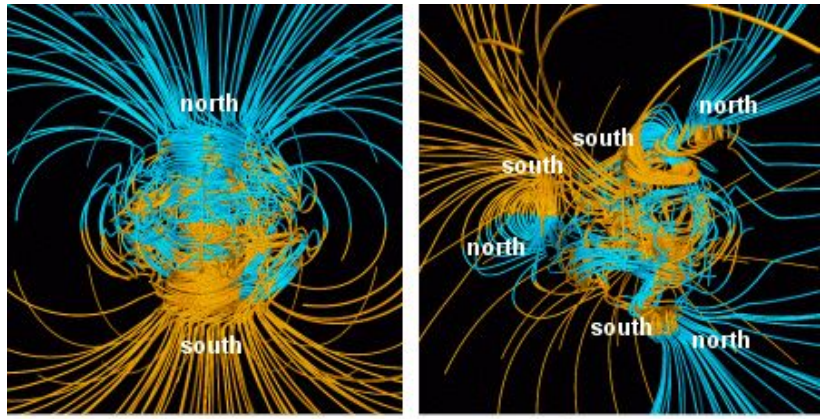
HEAMS - High Energy Astrophysics Muon System (8 x 1m^2 scintillator detectors, ~300k ~0.1 PeV air showers, location: Adelaide)

public resources:

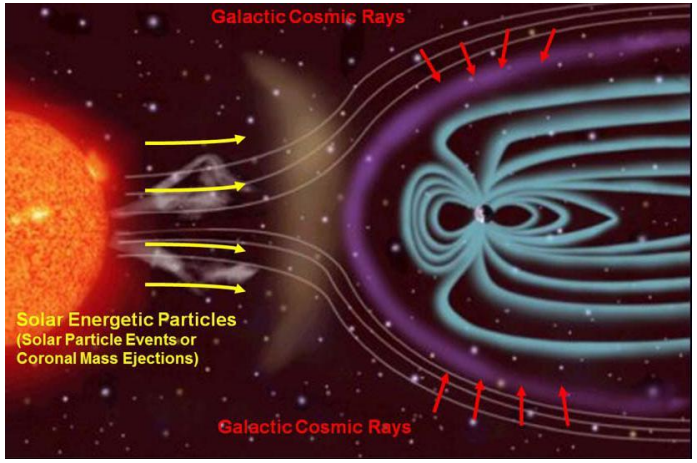
Pierre Auger Observatory scaler data, Neutron Monitor Database

short term perspective: GELATICA, CZELTA, other public resources

the COSMO-GEO precursor concept



Source: Wikipedia / „Geomagnetic reversal"



Source: Wikipedia / „Health threat from cosmic rays"

Earth outer core: Liquid (molten iron)
→ geomagnetism

↓

Impulse (tidal forces)
→ hydrodynamics: waves

↓

→ Mechanical wave upwards (slow, hours?)
→ Electromagnetic wave („instant", ms)

↓

Local/global geomagnetic field vector changes
AND seismic effect might occur!

↓

Variation of the CR rate!

↓

Earthquake precursors?

$N_{ATM} > 1$ motivated by data! (1)

VOLUME 50, NUMBER 26 PHYSICAL REVIEW LETTERS 27 JUNE 1983

Possible Observation of a Burst of Cosmic-Ray Events in the Form of Extensive Air Showers

Gary R. Smith, M. Ogmen, E. Buller, and S. Standil
Physics Department, University of Manitoba, Winnipeg, Manitoba R3T 2N2, Canada

(Received 7 April 1983)

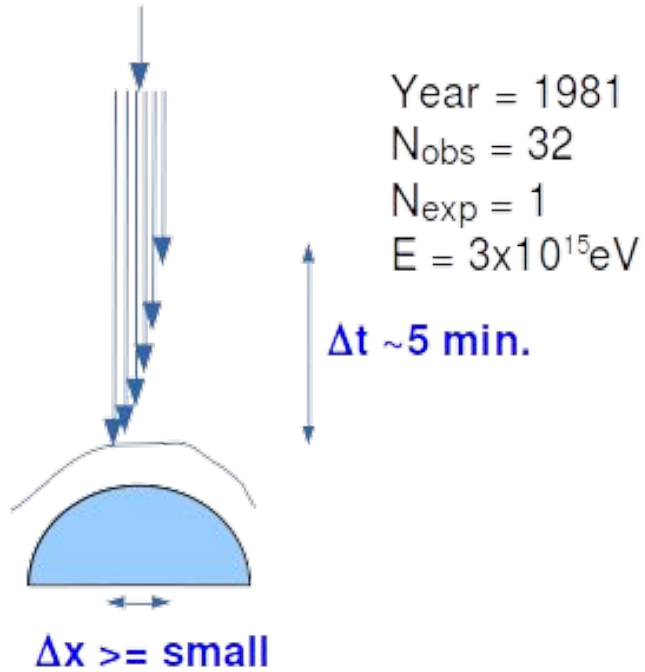
A series or burst of 32 extensive air showers of estimated mean energy 3×10^{15} eV was observed within a 5-min time interval beginning at 9:55 A.M. (CST) on 20 January 1981 in Winnipeg, Canada. This observation was the only one of its kind during an experiment which recorded 150 000 such showers in a total of 18 months between October 1980 and April 1982.

PACS numbers: 94.40.Pa, 96.40.Re, 95.30.-k

Forgotten (!) treasure (?) no. 1

PH: Correlated cosmic rays?

$N_{ATM} > 1$?



-> "Pay attention to data"!

$N_{ATM} > 1$ motivated by data! (2)

VOLUME 51, NUMBER 25 PHYSICAL REVIEW LETTERS 19 DECEMBER 1983

Observation of a Burst of Cosmic Rays at Energies above 7×10^{13} eV

D. J. Fegan and B. McBreen
Physics Department, University College Dublin, Dublin 4, Ireland
and
C. O'Sullivan
Physics Department, University College Cork, Cork, Ireland
(Received 14 September 1983)

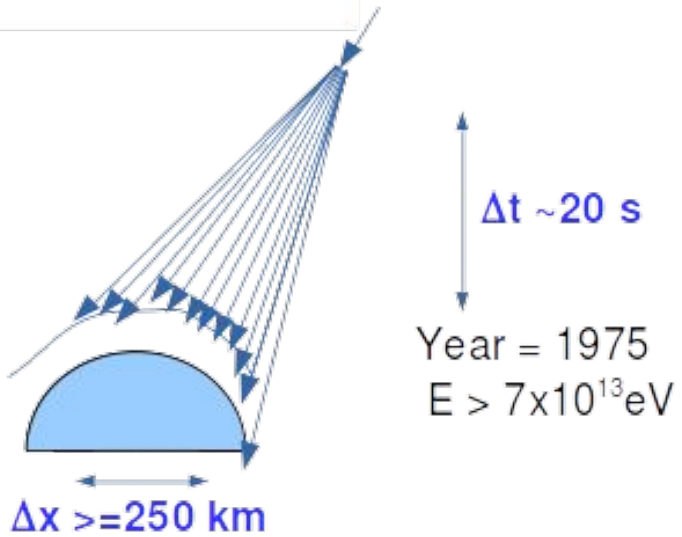
The authors report on an unusual simultaneous increase in the cosmic-ray shower rate at two recording stations separated by 250 km. The event lasted for 20 s. This event was the only one of its kind detected in three years of observation. The duration and structure of this event is different from a recently reported single-station cosmic-ray burst. The simultaneity of the coincident event suggests that it was caused by a burst of cosmic gamma rays. There is a possibility that this event may be related to the largest observed glitch of the pulsar in the Crab Nebula.

PACS numbers: 94.40.Pa, 95.85.Qx, 97.80.Jp

Forgotten (!) treasure (?) no. 2

PH: Correlated cosmic rays?

$N_{ATM} > 1$?



-> "Pay attention to data"!

The astro-geo direction

https://indico.in2p3.fr/event/18287/